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SOURCES AND TENDENCIES IN AMERICAN GEOLOGY

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AMERICAN leadership in invention and engineering is generally acknowledged, but what is our position in the various fields of science? It has been customary to look to Europe, and, in the last half century, especially to Germany as the leader in scientific achievement. In some lines this is no doubt true, but in other lines it is not true. The present, as the smoke of battle subsides, is an appropriate time to question old traditions now shaken loose before they settle again into fixed ideas. A study should be made of the contributions of the several nationalities both as to quantity and quality of productivity in each field of learning. The results of such a study of the progress of geology are given in this article and the conclusion is reached that for the past generation America, under which name should be included both the United States and Canada, has held a position of world leadership in that science. The order of importance of the other nationalities before the great war, taking the progress of the last half century as a measure, would be second, the British empire; third, Germany; fourth, France; but Italy, Scandinavia and Russia have also made notable contributions. If the place in geology held by the different nations be evaluated for the entire nineteenth century the order, in the opinion of the present writer, would be Great Britain, France, America, Germany; Great Britain being easily the leader.

In approaching this subject at the present time we must of course be careful in weighing the past contributions of Germany not to govern the verdict by the natural tendency to "trample them, they're down." The subject can, however, be tested in part by impersonal standards. Scientists are, as a class, unemotional creatures, and although those of the allied countries

unitedly condemn the criminal acts of the paranoiac among nations, those from whom the writer has secured data have shown a marked freedom from emotional bias. The conclusions expressed in this article are not new with the writer. In July, 1914, he had occasion to discuss the superficiality of the work of several German scientists on a certain geological subject and to point out their ignorance of the fact that English scientists had reached different and far sounder conclusions a generation previously. Yet the prestige of a German professorship had apparently blinded many American readers to obvious trivialities of argument.[1] On the other hand, the work of certain other German geologists should freely be recognized as of the highest grade, and their writings have marked notable advances in thought.

The broad attitude taken by von Zittel in 1899 is to be commended, as expressed in the following quotation:

> Although the present author of the "History of Geology" (von Zittel) was asked to depict chiefly the history of the growth of the science in Germany, the nature of the subject is such that it could not be successfully treated along national lines. All civilized nations have shared in the development of the natural sciences, the history of any one of which must be to a certain extent the history of a scientific freemasonry. The questions of the highest import in geology and paleontology are in no way affected by political frontiers, and the contributions to the progress of these studies made by members of any nationality can only be appreciated in their true values when held in the balance with the general position of research at the time, and with the discoveries and advances made by other geologists irrespective of nationality.[2]

Although the history of a science, as von Zittel states, can not be written with reference to any one nation alone, it is quite possible to recognize the relative contributions of the several nations.

In discussing the subject of the sources and tendencies of American geology, the first question which arises is as to the present content of geology. Every reader will feel sure that he knows what geology is, yet it is safe to say that few, except active geologists, are aware of the present scope of its subject matter and the lines along which research is now being pushed. The value of such a review as this may lie as much in giving a better perspective of the content of geology as in pointing out the relative contributions of different nations.

Popular ideas of a science are apt to lag a generation be-

[1] Joseph Barrell, "The Status of Hypotheses of Polar Wanderings," *Science*, Vol. XL., pp. 333–340, written July, 1914, published September 4, 1914.

[2] Karl A. von Zittel, "Geschichte der Geologie und Paläontologie bis Ende des 19. Jahrhunderts, 1899," English translation, pp. v, vi.

hind the real stage of advancement. In the popular imagination, geology is still supposed to consist largely on the one hand in collecting and naming rocks and fossils, the placing of these in proper sequence, and, on the other hand, theories of a rather speculative and uncertain character on the origin of the earth, its internal nature, and its history. As a matter of fact, there is but little in modern geology at its best which partakes of these characters. It has been said that a science in its growth passes from embryo to adult through the speculative, qualitative, quantitative, to predictive stages of development. Geologic research in the past generation has been passing out of the qualitative stage and has partaken notably of the quantitative character.

Geology, the science of the earth, is exceedingly broad in its scope and has developed into many branches, each of which rests more or less heavily upon some other science. From a division of natural history, whose early workers had little in the way of qualification other than powers of observation, acquisitiveness and a love of life in the open, it has passed into a group of special sciences. The elements of geology can be taught with advantage to students who have had no training in other sciences, being from the cultural standpoint one of the most broadening branches of knowledge, but research in the several fields now requires a thorough grounding in other sciences and such advanced training as is given in graduate schools.

Mineralogy has expanded into petrology. The form, composition and identification of minerals is of less interest than the broader questions which rise out of them. Leading toward physics, the orderly arrangement of the atoms in the crystal has been found to form a diffraction grating incomparably finer in spacing than any which could be made in the laboratory. The physicist, utilizing this, has solved the nature of the X-rays, and in turn this leads to a better knowledge of crystals. On the physico-chemical side, the crystallization of minerals from molten rocks is a problem of mutual solutions at high temperatures and is being investigated in the geo-physical laboratory. On the more strictly geological side, a mineral is a measure of the physical and chemical environment under which it originated. The secondary alterations taken in connection with the limits of stability of a mineral record the subsequent physical history of the rock of which it is a part. Minerals are thus geological thermometers and dynamometers. Their relations to each other, as seen under the microscope, show the order of crystallization; the assemblage, constituting the rock, gives a

definite record of environment and subsequent history. The mapping of rock types over the earth's surface proceeds, and out of it grow studies on differentiation—the changes through geologic time in the nature of molten rocks erupted in the same region. The fundamental relationships found within one region constitute the problems of consanguinity; by contrast, the unlikeness of different regions in earth composition mark out petrographic provinces. What are the meanings of differentiation, consanguinity and petrographic provinces? Such are the larger problems of petrology.

Paleontology, the ancient life history of the earth, was characterized a generation ago by the description and naming of species. There was a keen rivalry for priority and explorations were conducted to obtain new faunas. Almost no attention was paid regarding the associations of the fossil with the nature of the enveloping rocks, and but little to the exact stratigraphic level from which it was taken. To-day, in the hands of leaders, the description of new species is but an incidental task. From a keen study of the fossil, the form and habits of the living animal are inferred. The nature of the rock is used to restore the ancient environment, whether marine or terrestrial, swamp or arid plain. Fossils are collected and recorded foot by foot through a stratigraphic section, permitting the stages in the geographic shifting and geologic advancement of faunas to be followed. The areal limits of a fauna and the geographic distinctions serve as a means of delimiting ancient lands, seas and climatic zones. The study of the changes of life with respect to changes of environment and the passage of time throws valuable light on the causes and character of organic evolution. The perspective over long intervals of time gives a line of attack which is not possible to the student of living animals and plants. Thus the fossil, like the mineral, has become a means to an end;—those ends look toward a knowledge of the thing, a knowledge of its environment, a knowledge of causes and effects through vast periods of time.

Stratigraphy formerly consisted in but little more than measuring the thickness of sedimentary formations and mapping their areal extent. Formations of different regions were correlated by means of fossils and the sequence of the periods established. All sediments were assumed to be deposited in the sea, except such as contained remains of terrestrial organisms and were entirely devoid of those of the sea: such formations were regarded as deposited in lakes, although the fossils were commonly those of land plants and animals. This stage of development is now looked upon as merely having laid a ground-

work for the investigation of broader problems. The interpretation of the mode of origin of the sediments was narrow and conventional. At the present time, by contrast, the terrestrial deposits on broad river flood plains and deltas are seen to constitute an appreciable part of the geological record. Glacial débris in many older formations shows the recurrence of cold since very early geologic periods. At other times beds of salt and gypsum show widespread aridity. Each type of climate and topography is seen to be reflected in the nature of sediments. Through stratigraphy is thus built up the succession of past environments which paleontology peoples with living plants and animals. Between them these branches of geology are re-creating the geography of all the yesterdays, a subject taking form under the names of paleogeography and paleoclimatology.

During the past quarter century structural geology has grown to be a branch of large importance. It comprises several fields. That best known deals with the results of the forces of deformation acting upon older rock masses. Joints, faults, folds, schistosity are the expressions seen in a limited exposure. The merely descriptive stage of investigation is past. The faults must be classified into systems, their displacements ascertained and the position of severed portions of valuable ores located. Folds are analyzed into different orders of magnitude and the determination of the folded structures has led to the opening of iron deposits valued at many millions of dollars. The theories of deformational geology must thus meet the tests of verification and this necessity has stimulated the development of a quantitative accuracy. But this division of structural geology is the smaller part of the field, that dealing with details in the outermost crust. Passing to a larger scale, the nature of mountain structures has been greatly elucidated. In the past twenty years French geologists have given a new interpretation to the Alps based on great horizontally acting overthrusts. Vertical forces, uplifting faulted blocks, or warping upwards tracts which had acquired their mountainous structures long previously are found to be also fundamental as causes of mountain growth. The reasons for the existence of continents and ocean basins and the amount of their changes through geologic time is a still larger field of theory on which only a beginning has been made. Finally, geophysics is that field of structural geology in which precise geodetical and astronomical measurements are throwing light upon the distribution and character of density and rigidity through the crust and the deeper body of the earth. The ultimate causes of earth

structure are thus to be sought through the character of the insensible vibrations from far distant earthquakes and through precise measurements obtained by observations on the stars.

Physiography is a division of the new geology which had only feeble representation in the previous generation. This, the science of the earth's surface, consists of a study of forms and causes. It embraces the effects of surface activities, a field known also as dynamical geology, and seeks through them the causes of the forms of the lands from the smallest to the largest features. In the middle of the last century valleys were still supposed to be determined by rifts and depressions in the crust, although Hutton and Playfair had shown clearly long before that the valleys were carved by running water. The existing mountain ranges were regarded as elevated at the close of the period of the youngest formation entering into their structure and were thought capable of enduring in subdued form through all of geologic time.

The beginning of the present development rested on the recognition that erosion by rain and rivers carried to the limit would result in a surface nearly plane cut across all rock structures and developed near the level of the sea. Davis, thirty years ago, named such an ultimate land form a peneplain. Distinguished by a name, they were then recognized, though now uplifted and in various stages of destruction, in many mountain regions. A new means had been found of studying mountain history. Uplift initiates a new cycle of erosion with respect to a new baselevel. Applying this principle, a landscape is now interpreted as but one stage in a sequence of forms, passing from some initial stage of uplift toward a featureless plain of erosion lying at the level of the sea. Geologic time is seen to be so long in comparison with the time needed to level the loftiest mountain range that folding and uplift must have occurred again and again since the earliest ages in order to provide sources for the sediments which have built up the stratigraphic series. The present upland and valley forms show in every continent from the youth or early maturity of the present erosion cycles that the world is girdled with very young mountains, even where their rocks and structures are very ancient. The present geologic period is consequently seen to be one of profound terrestrial revolution, a conclusion of high importance in our understanding of the earth and the relations of man to his dwelling place and the causes which gave him birth.

Lastly there has grown to high importance the branch of economic geology. This was formerly regarded as consisting in a description of ore deposits and building materials accom-

panied with statistics of production. That original field has become only one section of the subject. Economic geology has recently been defined by the director of the United States Geological Survey as "useful geology." Another definition expressive of its content and purpose is that economic geology is applied geology. Pure science, the search for new knowledge for its own sake and without thought of its applications, becomes applied science in the most unexpected ways. Every division of geology has contributed to the advancement and expansion of economic geology. Petrologic and chemical geology, stratigraphy and physiography, all lead to the study and conservation of soils, the basis of agricultural wealth. The working out of stratigraphy and structure permits intelligent search for the stores of underground water, the most valuable of minerals in many parts of the national domain. A knowledge of the structure and character of the foundation rocks can be given by the geologist to the engineer and military chief, of great importance toward the success of foundations, dams, roads, canals and military works. A knowledge of stratigraphy and structure has led to the discovery of coal basins concealed beneath younger strata. Hundreds of young geologists are now being employed by the great petroleum companies to study the stratigraphy and structure mile by mile over great areas of country in the search for mineral oil. Mining geologists are now retained permanently on the staffs of many large companies to study and map in detail the relations of complex ore deposits as a guide to more intelligent development in mining. Physiography also is making its contribution to the location of copper, manganese, and other deposits; since where these have been concentrated through the agency of circulating underground waters the recognition of the former stages of erosion serve as a guide to present location. Other geologists are employed on state and national surveys, classifying lands, discovering and mapping the areas of valuable deposits such as coal, iron, potash, and phosphates for the benefit, now and in the future, of all the people of the nation. A higher field of economic geology is that of the conservation of national wealth. It is not an overstatement to say that the future welfare of mankind through unnumbered centuries yet to come depends upon the spread of education in regard to the limitations of mineral wealth and the development in the national consciousness of the creed that each generation holds the treasures of the earth in trust for the future, to be used but not squandered by the temporary trustees.

Let us turn from this survey of the present viewpoints of

geology to a review of its growth and note whence have come the fundamental ideas which from generation to generation have expanded its fields of theory and usefulness.

Speculations on the origin and history of the earth once formed a favorite theme for philosophers. Omitting from consideration the ancients, such men as Descartes and Leibnitz devised theories of cosmogony which represented advances in thought; but such systems of philosophy, not founded on field observation and inductive reasoning should be sharply distinguished from the science of geology. A science rests upon careful observation, classification of observations, framing of hypotheses to relate the facts to each other, and testing of the hypotheses by further observations. There must be both induction and deduction, for the groundwork of geology to justify its name must rest on a patient study of the earth. The grand schemes of the cosmogonists, notwithstanding their stimulation to thought, perhaps served more to retard than to aid the development of real science. In the latter half of the eighteenth century geology became firmly established on a groundwork of fact as a result of the labors of a few men in France, Italy, Germany and Great Britain, of whom the philosophers took no recognition. Guettard, Demarest, Arduino, Lehmann, Füchsel, Smith and Hutton are the men who stand forth, but the greatest of these was Hutton.

Hutton, regarded as the founder of modern geology, was born in Edinburgh in 1726 and died there in 1797. He held no university position but pursued his investigations solely from their inherent interest. He did not publish his views until 1785, and beyond the circle of his friends they attracted little attention until after Playfair in 1802 published his classic volume, "The Huttonian Theory of the Earth," in which he condensed and clarified the work of his friend into much more readable form. Hutton saw the evidence that the great masses of granite which so commonly underlie the stratified rocks had originated by crystallization from a melted state and had risen in molten form into the outer crust from the depths of the earth. The folding, upturning, mashing and crystallizing of the sedimentary rocks he saw was due to the vast forces within the crust aided by internal heat. Great crust revolutions resulting in the uplift of mountains were followed by prolonged weathering and erosion of all rocks above the level of the sea. New sedimentary formations from the débris of other lands were then laid down across the eroded edges of the rock formations of an older world. The forces now in operation he held were capable through unlimited time of effecting these stupen-

dous results, time and time again. Back of each older world were the ruins of a world still older. In Hutton's words, "we find no vestige of a beginning—no prospect of an end."

These magnificent conceptions were not cosmogonic speculations, but were founded on close and prolonged observations. They were generalizations which had been seldom glimpsed and never before clearly seen or proved through two thousand years of intellectual endeavor. Because the Huttonian theory of the earth was distinguished by giving an important place to the heat and deforming forces of the inner earth, those who accepted Hutton's ideas were called Plutonists.

Twenty-three years later than Hutton the mineralogist Werner was born in Prussian Silesia. In 1775, at the age of twenty-six he was appointed inspector and teacher of mining and mineralogy in the Freiberg Mining Academy. For forty-two years he continued in this position and was throughout that time enthusiastically regarded by those who listened to his lectures as an oracle on the history and rock formations of the entire earth. To this subject he gave the name of geognosy and his students went forth with the fervor of disciples to spread his doctrines. With a personal knowledge limited to Saxony and Silesia he nevertheless advocated with dogmatic conviction the idea that the rock formations shown there were universal in their extent and occurred everywhere in the same definite order. He did not believe that any rocks originated from the molten state. Volcanoes were to him nothing more than local and superficial outbreaks, the results of the burning of coal beds. The oldest and underlying rocks, showing a crystalline structure such as granite and gneiss, were classified as Primitive and asserted to be the precipitates from a primal universal ocean. Their crystalline nature was held to be a proof of this aqueous origin. Above the Primitive came the Transition series, followed by the Flœtz rocks, partly of chemical origin but in which mechanical sediments began to dominate. Coal, basalt, obsidian, porphyry, etc., were included in the Flœtz series as chemical deposits. Werner offered no reasonable explanation as to what became of the primeval universal ocean and he opposed all conclusions which rested upon the action of internal heat or deforming forces. He would not admit that mountains had been elevated or strata folded. From the disbelief of the Wernerians in the internal agencies of the earth and their assertion that all crystalline rocks had been precipitated from ocean waters they were named the Neptunists.

One of Werner's pupils, Robert Jameson, became professor

of natural philosophy in Edinburgh, the very home of Hutton and Playfair, whose work Jameson treated with contempt. For several decades, up to the time of Werner's death in 1817, his system of geognosy was dominant. A bitter warfare was waged between Plutonists and Neptunists, characterized on the part of the latter by provincial ignorance, dogmatic assertion, arrogance in place of demonstration. But the accumulation of incontestible facts undermined the morale of the system, showed that it was false from the foundation upward, and within a few years after Werner's death the whole had collapsed like a house of cards. Von Zittel in his excellent and impartial "Geschichte der Geologie und Paläontologie" states that the erroneous views held by Werner appreciably retarded the progress of geology, and in Germany after the collapse of his system the science of the earth seemed for a time to make no progress.[3]

Werner's real contribution lay in his orderly classification of minerals and rocks. Hutton's contribution on the other hand was nothing less than the establishment of the broad science of geology on a secure foundation.

The wide proclamation of Werner's system contrasted to the lack of advertisement of Hutton's is perhaps significant of the difference in national characters and is seen to show a certain parallelism to the developments of science and to the German propaganda a century later. The diverse racial stocks which made up the German empire, notwithstanding their belief in racial unity and superiority, have resulted in a wide range of temperament and ability, but Werner the Prussian is typical of the dominant national tendency to classify, to systematize, to consider this as the field of science, and with arrogant dogmatism to either discount or appropriate fundamental ideas originating elsewhere. A similar spirit has been sporadically manifested by individuals of other lands, but never with that frequency which would permit its development into a dominating national characteristic.

Near the close of the eighteenth century and opening of the nineteenth an era of scientific exploration set in. Three Germans—Pallas, von Humboldt and von Buch—were most noteworthy, Pallas being employed by the Empress Catharine of Russia, von Humboldt and von Buch being men of independent means. The energy and ability of these men contributed very much to a knowledge of the world, but to geological theory they themselves added comparatively little. The real growth of geology in the first third of the nineteenth century was largely in Great Britain and France. The advance is represented by the

[3] Pp. 48, 427, English translation.

appearance of manuals in French, German and English, culminating in the English works of De la Beche and Lyell, books which may be studied with profit even at the present day. The work of Cuvier and Brongniart had in France established paleontology during this same interval as a progressive branch of science.

With the opening of the second third of the nineteenth century the United States began to make notable contributions to geology. The initiation of state geologic surveys between 1830 and 1840 and of the Canadian surveys shortly afterward began an era of systematic and detailed scientific exploration in North America which in this regard led the world. In this same middle third of the century Darwin went on the voyage of the *Beagle*, and Dana as geologist and zoologist on the Wilkes exploring expedition. The geologic history of India, South Africa and Australia began to receive attention. In England Sedgwick and Murchison established the larger divisions of the Paleozoic era and in New York the detailed stratigraphy was worked out, with the result that locality names from England and New York dominate in the nomenclature of the Paleozoic.

In the field of theory Lyell established beyond controversy the principle which lies at the basis of all geologic science, that the past is to be interpreted by the study of causes now in operation. Elie de Beaumont in France, Dana and Hall in America, placed the theory of mountains upon a secure foundation. Bischof in Germany in his admirable text book of chemical and physical geology, published in 1846, made that country a leader in the division of geo-chemistry. From 1850 to 1858 the British geologist, Sorby, developed the methods for the microscopic examination of rocks. This through the German geologist Zirkel led to the great development of modern petrology which for the following twenty-five years, transplanted from England, became a distinctively German branch of science. Last, but not least, is to be mentioned the work of Charles Darwin which established the existence of organic evolution upon an unassailable basis.

In the last third of the nineteenth century appeared from Vienna the great work of Suess on "The Face of the Earth," welding into one treatise the geologic literature of the world and developing new views on the nature of continental and mountain-making movements. In Scotland the existence of great overthrust faults was demonstrated by British geologists, it being proved that ancient crystalline rocks had been shoved for more than ten miles over younger stratified formations. In France, before the end of the century, a new interpretation of

the Alps, of wide application over the earth, began to be conceived. Folding was seen to have passed into great overthrust sheets and erosion to have later cut these into remnants, leaving on the north side of the Alps mountains whose rocks had been deposited in previous ages far to the south, mountains without roots as they have been picturesquely called.

It was in America, however, that from 1867 to 1900 the greatest expansion of geology took place. After the close of the Civil War, under the auspices of the government, a group of young men of remarkable energy and ability began the scientific exploration of the western United States. The names of Powell, Dutton and Gilbert stand out above a worthy company and came to be known to geologists through both hemispheres. Their work laid the basis for the new science of physiography, developed so largely by Davis, which for the latest geologic epochs reveals the detailed history of the lands as the sequence of stratified rocks does for earlier ages. In the central part of the continent Chamberlin was establishing during this period the complexity of the Pleistocene, Irving and Van Hise were applying new methods and by them unraveling the structure of the ancient iron-bearing rocks of the Lake Superior region. In the field of paleontology Cope and Marsh explored the Tertiary and younger Mesozoic rocks of the west and brought forth from their stony tombs a legion of extinct vertebrates whose march across the stage of time made visible beyond question the story of their evolution.

Measured by the activity of its workers, by the immensity of its field, by the contribution to new ideas, it appears that by the year 1890 North America had taken a place of world leadership in geologic science. In the twentieth century, through many able workers in Canada and the Lake Superior region, our knowledge of the earlier geologic ages previously grouped under the name Archean has become expended into a complex history comparable in number of events and in duration to all subsequent time. A corresponding history has been worked out for their portion of the world by Scandinavian geologists.

With the increased knowledge of terrestrial processes as exhibited in continental interiors it has been shown by British, German and American geologists that the character of the topography influences the nature of the sediments, important formations are laid down in river basins and in deltas as terrestrial deposits. The first recognition of this importance of terrestrial deposition is to be credited to the British geologists in India. Wind has been shown by von Richthofen, Pumpelly, Walther and Passarge to play an important part in transporta-

tion, but some time before Darwin made note of the enormous quantities of dust swept into the Atlantic from the Sahara. The winds on the Indus delta were shown half a century ago to be as important as the river currents. Desert dunes are the waves of a migrating sea of sand. Eolian transportation and deposition is now given a large place in geologic theory. Climate is seen to be a major factor in controlling the character of even fluviatile and marine sediments, determining their structure and their content of iron and carbon. This more precise knowledge of the present has made possible a revision in that interpretation of the past which is derived from the study of the stratified rocks. Frequent breaks in sedimentation have been shown, chiefly by American geologists, to occur throughout the stratigraphic series, the larger of these, representing oscillations from sea to land and back to sea again, give rise in the strata to unconformities and disconformities. All of this new knowledge, most largely of American origin, is giving a clearer view of the oscillations of land and sea, of humidity and aridity, of heat and cold, and is establishing, as previously noted, two new divisions of historical geology—paleogeography and paleoclimatology.

The application of geology to the service of man, the field of economic geology, has undergone also a great expansion during the past generation, chiefly in America. Recognition of the usefulness of geology must result in advantage to the entire subject. It tends to draw more men into its ranks, it brings to the work a greater political respect, and from the ranks of the younger geologists who are able to win a living in useful geology will develop those capable of advancing the theoretical aspects of the subject.

Having given this survey of the past progress of geology, let attention be turned toward its probable future. The center of the greatest advancement during the next generation should be in North America. The preliminary survey of this continent has already been made. To men of limited vision it may have seemed that nothing of a large nature remained to be done. As a college student once said—he did not care to go into geology because since Dana had written his manual nothing remained to do except to fill in the details. Those engaged in research on the larger problems, however, are thankful that the continent has been studied and mapped to the present degree, since this preliminary work paves the way for an ever-expanding field of higher research. Such investigation must go hand in hand also with a more detailed and critical mapping which in

the United States alone bids fair to engage the energies of geologists for a century to come.

Another large field for the employment of geologists is as teachers in the universities. In the larger institutions of learning geology is recognized as of high cultural value, comparable to biology, serving to expand the mind of the student as do few other subjects. The history and nature of the earth and its inhabitants is an appropriate background for the understanding of the history and nature of man.

But although the preliminary geological survey of North America has been made, a considerable part of the land surface of the world is as yet imperfectly known. South America, especially, is a continent regarding which there is much to learn. Geological instruction in our graduate schools should be elastic and comprehensive enough to serve as training for men to work in other lands. Modern languages must be insisted upon as prerequisites for the higher degrees, not only as means of gaining access to the literature of other nations, especially France, Germany and Italy; but also as a means of facilitating research beyond the bounds of the English-speaking world, in such lands as South America, Siberia and China. The limitations of time forbid the requirement of more than two modern languages, but some knowledge of three or four would for those of natural linguistic abilities be of distinct advantage.

Another region which is as yet almost a *terra incognita* but which is open to future research is the great interior of the earth. A beginning has been made through geodesy, seismology, the geophysical laboratory, the nature of igneous rocks, and the forces which express themselves in deformation of the crust, but there is as yet much difference of opinion as to even the major conclusions. No secure knowledge can be had, however, as to the larger problems of the earth, such as its mode of origin, the source of igneous rocks, the causes of continents and ocean basins, until more is known with certainty and in detail of the earth's interior. This perhaps is the most difficult field of geologic science, requiring organized attack through the funds of institutions for scientific research, but it is a field whose tillage will yield rich returns.

This survey of the present standing of geology has been necessarily brief. Important subdivisions and fields of research have been wholly omitted, but the purpose of the article has been accomplished if it has shown in true perspective the contributions of different nations to the growth of geology, the branching out which has taken place from the parent trunk, and the resultant wide scope for future research in the science of the earth.